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San Diego, CA   92128 -1842

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We completed successfully the construction of three prototype burst lasers for CBRNE detection applications. The lasers are very compact, low cost and meet all the original solicitation specifications. In addition, it delivers 266nm and can operates on portable battery for field applications.

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Report Title

Final Report: Compact, Rugged, and Low-Cost Wavelength-Versatile Burst Laser

ABSTRACT

We completed successfully the construction of three prototype burst lasers for CBRNE detection applications. The lasers are very compact, low cost and meet all the original solicitation specifications. In addition, it delivers 266nm and can operates on portable battery for field applications.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

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TOTAL:

Number of Papers published in peer-reviewed journals:

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TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

<u>Received</u>   <u>Paper</u>

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

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TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

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Number of Manuscripts:

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<u>Received</u>   <u>Book Chapter</u>

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Dylan Burns	0.30
FTE Equivalent:	**0.30**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Dryver Huston	0.20	
FTE Equivalent:	**0.20**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

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This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

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Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

1 a. University of Vermont   **1 b.** 85 South Prospect Street, 340 Water

                                                 Burlington   VT   054050160

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

**Work Description (e):** Mechanical design and construction of prototype burst laser.

Sub Contract Award Date (f-1): 4/18/13 12:00AM

Sub Contract Est Completion Date(f-2): 4/17/15 12:00AM

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1 a. University of Vermont   **1 b.** Office of Sponsored Programs

                                                  85 S. Prospect Street

                                                  Burlington   VT   054050160

Sub Contractor Numbers (c):

Patent Clause Number (d-1):

Patent Date (d-2):

Work Description (e): Mechanical design and construction of prototype burst laser.

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Sub Contract Est Completion Date(f-2): 4/17/15 12:00AM

Inventions (DD882)

Scientific Progress

see attachment

Technology Transfer
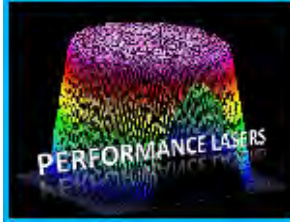
Compact, Rugged, and Low-Cost Wavelength-Versatile Burst Laser
(Army STTR)

Final Technical Report
April18, 2013 to April17, 2015

Proposal Number: A2-4987

Contract Number: W911NF-13-C-0050

Table of Contents

1. List of Illustrations

Project objectives

Many laser-based sensor technologies like Raman, Laser Induced Fluorescence (LIF), UV Laser Photo-Dissociation (UV-PD), and Laser Induced Breakdown Spectroscopy (LIBS) are being developed for close contact and standoff threat chemical, biological, radiological, nuclear and explosives (CBRNE) analysis. These operate in a burst laser mode with a finite number of laser pulses required for the measurement. This is because either the sample/target is chemically altered with repeated laser shots, or the technique limits the number of shots for rapid sensor response.

The typical pulsed lasers currently used in these systems are Commercial off the Shelf (COTS) systems that have been designed for continuous operation for many hours. Therefore, these lasers are over engineered with regards to size, weight, cooling capacity, and cost.

Currently the most affordable pulsed laser systems are flashlamp pumped. However, diode pumped lasers are more desirable due to ruggedness, higher efficiency, and smaller size. So far, the Diode Pumped Solid State (DPSS) lasers have cost significantly more than flashlamp pumped lasers.

Our STTR project has the goal of producing DPSS burst laser that is (1) high pulse energy in a rapid burst mode, (2) wavelength agile to cover the eye-safer regions in the UV and near-IR, as well as (3) smaller, lighter, and much more affordable than current COTS systems.

Phase I started on August 31, 2011 and ended on February 28, 2012. Although the Phase I requirement was to produce an engineering model for the burst laser, we have taken it much further and built a breadboard demonstrator and successfully demonstrated its performance.

Burst Laser Goal Requirements:

- 50mJ/pulse @ 1064nm
- 5 - 10ns pulse duration
- <3xDL (Diffraction Limited) beam quality
- Other wavelengths options of 1.5μm and 355nm
- Up to 100 pulses burst
- <100Hz repetition rate (10Hz is sufficient)
- <1 minute between bursts
- <33% of current laser size (<850 cubic inch)
- <25% of current laser weight (<8.5lbs.)
- <33% of current laser cost (<$8,500)

In Phase II (April 18, 2013 to April 17, 2015) our goal was to engineer, design and construct three prototype burst laser systems that show the feasibility of producing such lasers while meeting all of the above goal requirements.

Work Performed and Results Obtained

Phase II Technical Objectives and Approach
The technical objective of Phase II is to build and test three low cost prototype burst lasers that meet all the US Army requirements.

The approach to reach the above objective is by performing the following tasks: 1) design, fabrication, components procurement, assembly and testing of first prototype laser system based on Phase I effort, 2) incorporate new low cost diode arrays and address minor modifications if needed in updated design, then fabricate, procure components, assemble and test the next two prototype lasers and upgrade the first laser to the latest design.

Kickoff Meeting (May 2013)
The Phase II program started with a kickoff meeting that included the US Army representatives. Planned actions were described, followed by an open discussion on any deviations from the intended plan.

Year 1 Schedule

ID	ⓘ	TaskName	April	May	June	July	August	September	October	November	December	January	February	March	April
1		**Year 1**													
2	▦	Kickoff preperation													
3	▦	Kickoff meeting		◆ 5/8											
4		**First Prototype laser**													
5	▦	Laser preliminary design													
6	▦	Preliminary design review				◆ 7/17									
7	▦	Detailed design													
8	▦	Final design review						◆ 9/17							
9		Fabrication													
10	▦	Procurment													
11	▦	Assembly													
12	▦	Testing													
13	▦	First prototype laser complete													◆ 4/1
14	▦	Low cost diode array developme													

Year 2 Schedule

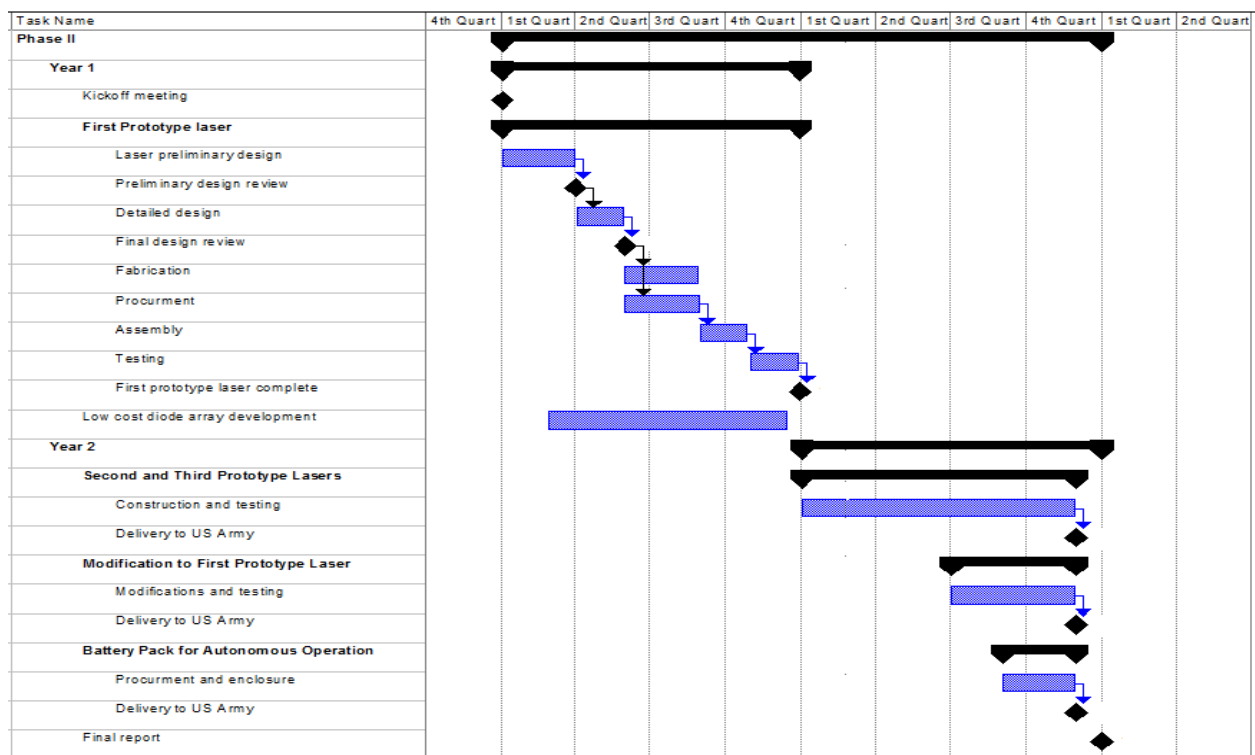| Task Name	4th Quart	1st Quart	2nd Quart	3rd Quart	4th Quart	1st Quart	2nd Quart	3rd Quart	4th Quart	1st Quart	2nd Quart
Phase II											
Year 1											
Kickoff meeting											
First Prototype laser											
Laser preliminary design											
Preliminary design review											
Detailed design											
Final design review											
Fabrication											
Procurment											
Assembly											
Testing											
First prototype laser complete											
Low cost diode array development											
Year 2											
Second and Third Prototype Lasers											
Construction and testing											
Delivery to US Army											
Modification to First Prototype Laser											
Modifications and testing											
Delivery to US Army											
Battery Pack for Autonomous Operation											
Procurment and enclosure											
Delivery to US Army											
Final report											

Laser System Concept

The laser system under development in Phase II is intended for both in house and field applications. It is designed to be used with a standard wall plug of 115Vac or with a 12Vdc and 115Vac inverter as shown in figure 1.
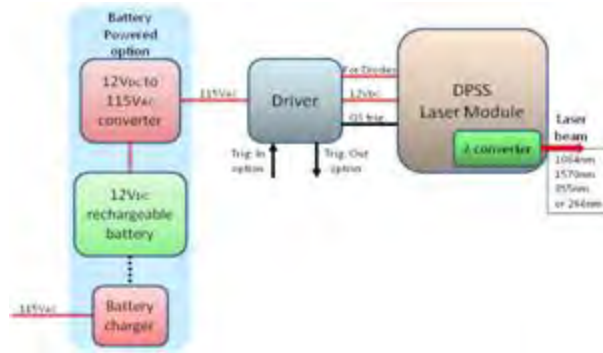
Figure 1 – Block diagram of the burst laser system

The Diode Pumped Solid State (DPSS) laser module produces 50mJ per pulse at 1064nm. The wavelength can be converted to 1570nm, 355nm or 266nm via the wavelength converters. The laser drive electronics is a separate module connected via a cord to enable more flexibility of operation. The laser driver plugs to 115Vac and has trigger IN and trigger OUT for synchronizing it with other detection equipment. For field application, a 12Vdc battery and inverter to 115Vac is provided. It can be hooked to a car battery with inverter or the provided battery pack.

Master Oscillator Power Amplifier (MOPA) Laser Configuration

Lasers that are used for LIBS and other optical based detections like LIF, Raman, etc. are simple laser oscillator design and flash lamp pumped for low cost. Operating a simple laser oscillator at high energy per pulse requires a trade-off between energy per pulse and beam quality. Higher energy per pulse translates to lower beam quality. We have chosen to go with diode pumped MOPA laser configuration for high performance. For this proposed burst laser we want high beam quality to allow for generating micro-plasma for LIBS at large standoff distance, and also for improved performance of the wavelength converters.

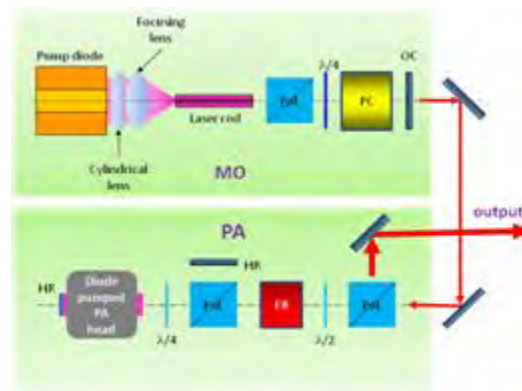Figure 2 shows our 4 pass Master Oscillator Power Amplifier (MOPA) laser configuration.

Figure 2 – 4 pass Laser MOPA configuration

The Master Oscillator (MO) is a longitudinally pumped Q-switched Nd:YAG laser. The pump diode build up the population inversion in the Nd:YAG rod during the pump duration of about 200µs. The polarizer and the quarter waveplate prevent any lasing until the Pockels cell activates and undoes the quarter waveplate to allow lasing. The laser light escapes the resonator through the output coupler (OC). In this configuration, the pulse duration depends on the gain and the resonator length. The Power Amplifier (PA) is a passive four pass amplifier that boosts up the energy per pulse without affecting the beam properties.

In Year 1 of Phase II we constructed and tested the 4 pass MOPA laser. Figure 3 shows the layout of the laser.
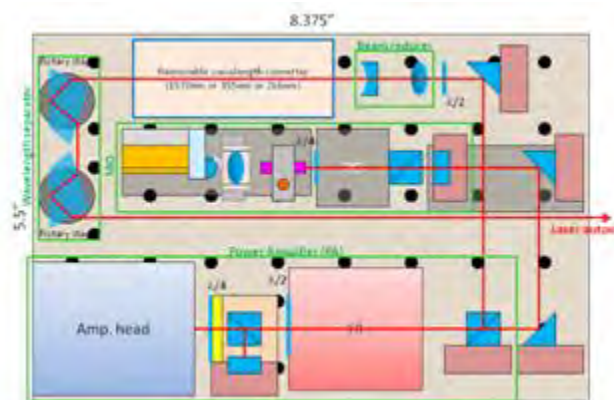

Figure 3 – 4 pass Laser MOPA layout

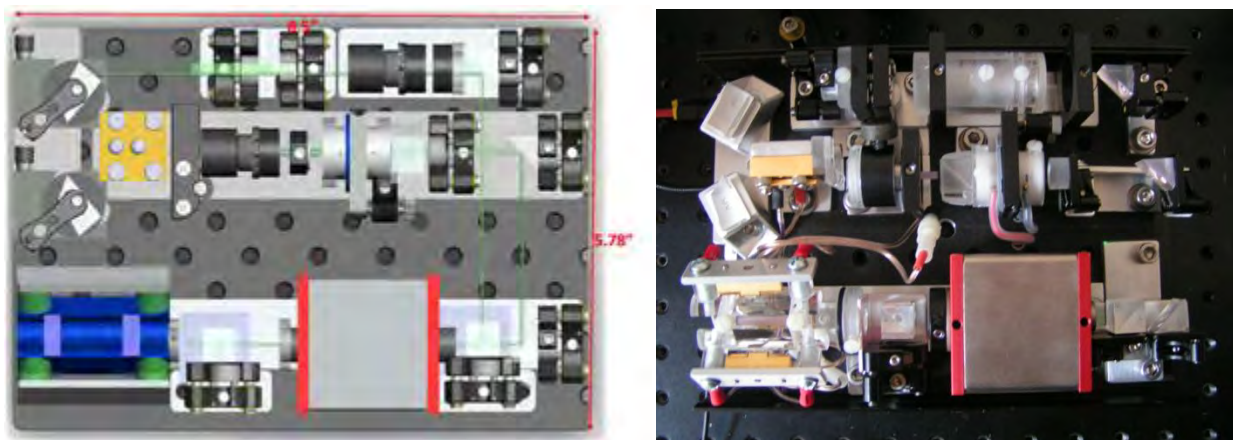Figure 4 shows the design and a photograph of the 4 pass laser.

Figure 4 – 4 pass Laser MOPA design (left), and photograph (right)

By designing the laser for small size it was more difficult to get the laser to reach its desired performance. In addition, the high cost and weight of the Faraday rotator was a concern. In order to reduce the cost and weight, we modified the design. We increased the power out of

the Master Oscillator (MO) and changed the Power Amplifier (PA) configuration to 2 passes as shown in Figure 5.
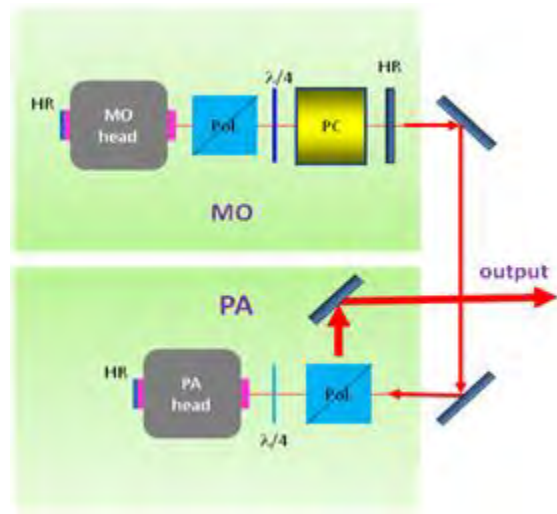

Figure 5 – 2 pass Laser MOPA configuration

Diode Arrays for the New MOPA Configuration

Diode arrays are the major cost components of the laser. We selected low duty cycle diode arrays with no cooling. The diode arrays were tested using 100 pulse bursts. The red shift of the arrays was ~1.5nm which is within the required range of 3nm. We observed the wavelength shift live using a real time spectrometer.

Q-Switched MO

The new MOPA configuration requires higher energy per pulse in order to achieve the 50mJ output after only two pass amplification. We modified the MO design to have higher pump power and larger laser rod. A laser diode array is transversely pumping a 4mm diameter rod.

Figure 6 shows the MO that we designed and constructed.

Figure 6 – New high pulse energy Q-switched MO

This MO delivers ~15mJ per pulse and 8 to 10 ns pulse duration.
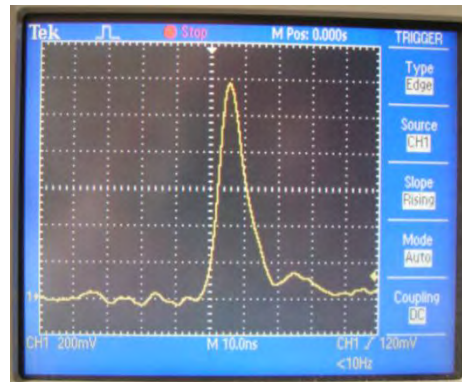
Figure 7 shows the MO temporal pulse.

Figure 7 – Q-switch MO 8ns FWHM temporal pulse

Figure 8 shows the MO output pulse energy versus the drive current the diode array.
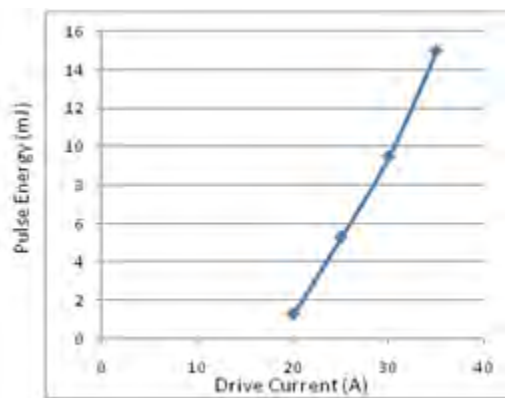

Figure 8 – Q-switch MO pulse energy

Figure 9 shows the spatial beam profile. The slight elongation is due to the pump array, but the beam is nearly diffraction limited and Gaussian in profile.
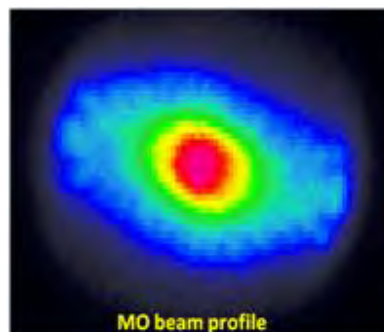

Figure 9 – Q-switch MO spatial beam profile

Power Amplifier (PA)

Burst mode operation is different than a typical laser operation. A typical solid state laser must run at a constant loading to maintain steady thermal conditions. Solid state lasers change their performance as components change their temperature. Laser diodes undergo red wavelength shift at elevated temperature, the laser crystals and harmonics generation crystals start lensing and the thermal stress induce birefringence. All this change need to be compensated to avoid laser performance degradation. Burst mode operation takes the laser components from low temperature to elevated temperature during the burst duration. In this case we have to ensure that the laser components will be within the range of acceptable performance.

The PA was designed and fabricated completely in house. It consists of a single diode array that transversely pumps a 4mm Nd:YAG laser rod. A photograph of the PA laser head is shown in figure 10.

Figure 10 – *Photograph of the PA laser head*

MOPA Performance

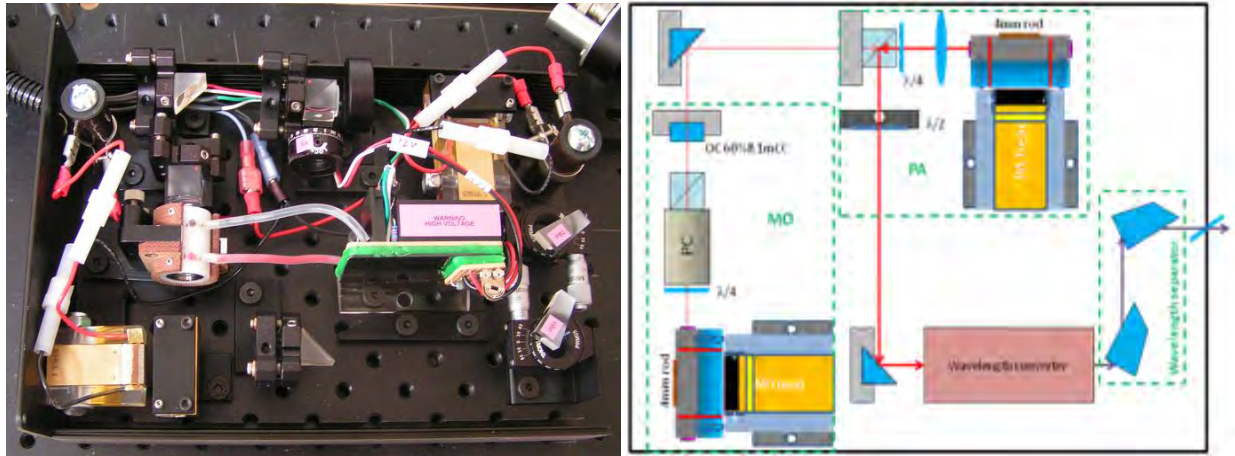The MOPA layout is shown in figure 11.

Figure 11 – *MOPA layout on the right with the wavelength converter, and the actual MOPA on the left without the wavelength converter*

The MOPA pulse energy and temporal pulse are shown in figure 12. The FWHM was between 8ns to 10ns for the various burst lasers constructed.
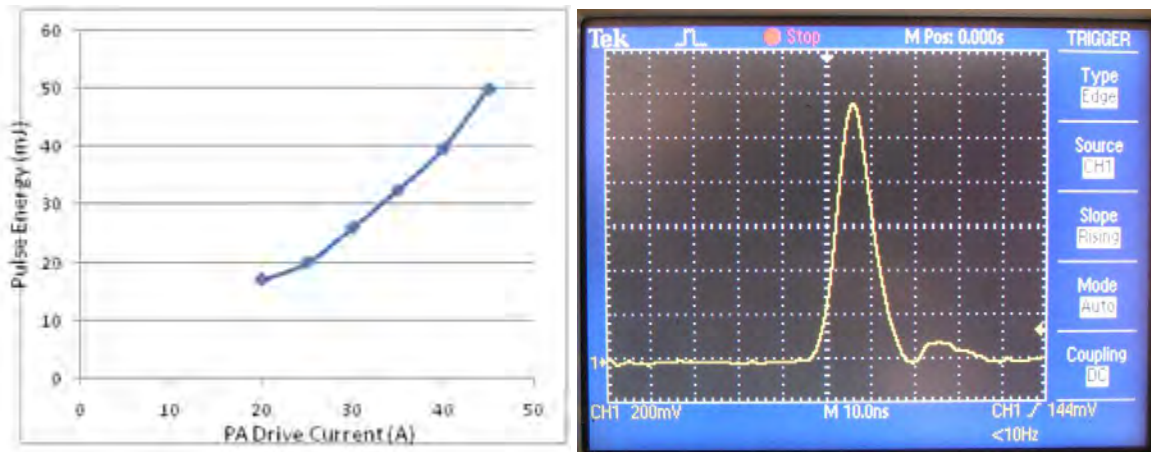

Figure 12 – *1064nm MOPA pulse energy versus laser diodes' drive current (left) and the temporal pulse (right)*

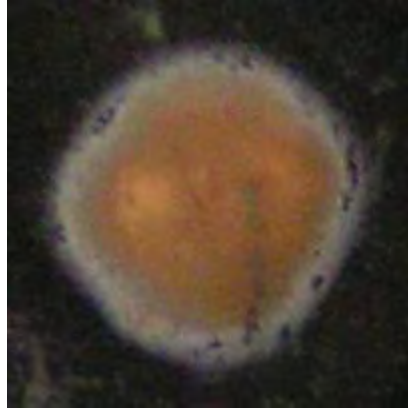Figure 13 is the burn pattern of the MOPA output pulse.

Figure 13 – Spatial burn of the 1064nm MOPA pulse (4mm diameter and 50mJ/pulse)

Wavelength Converters

The laser system has the option to generate other wavelengths of interest by converting the fundamental wavelength of 1064nm.

1570nm Converter

For safe operation in the field, it is a standard practice to use eye safe wavelength like 1.5µm. There are several techniques for shifting the fundamental to longer wavelengths. The most elegant, efficient and compact is by using OPO (Optical Parametric Oscillator). The set-up for the converter is shown in figure 14.
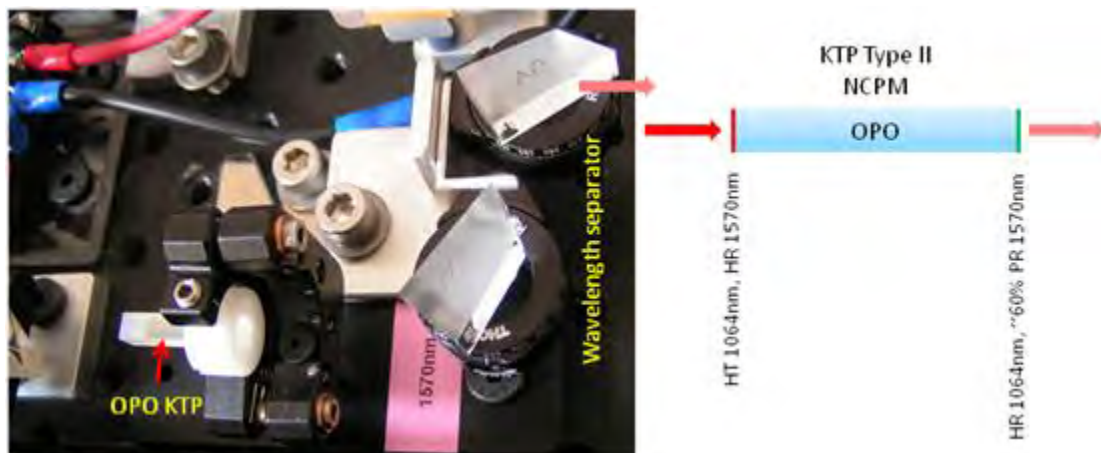

Figure 14 – Eye safe OPO KTP converter and wavelength separator

The optical coatings are done on the crystal itself in order to reduce size and cost.

We obtained pulse energy of about 3.3mJ at 1570nm, and pulse duration of 10ns as shown in figure 15.
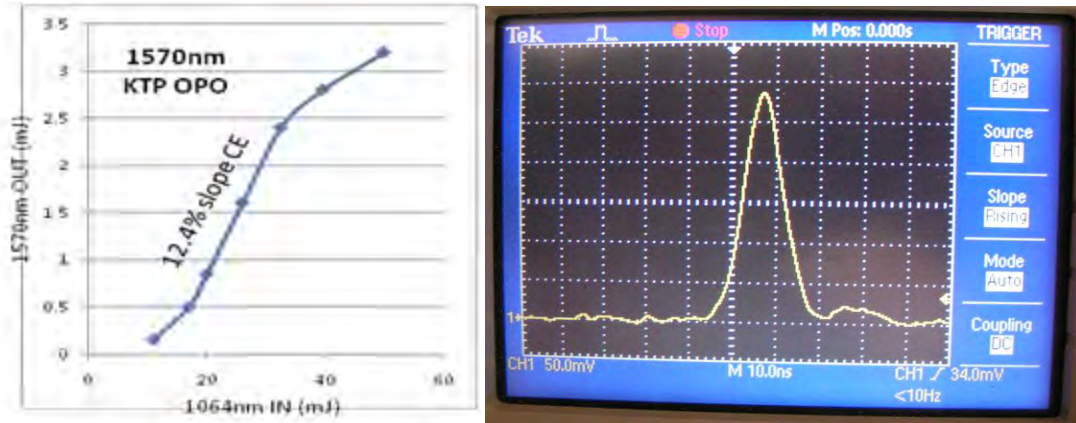
Figure 15 – *1570nm converter pulse energy and temporal pulse*

355nm Converter

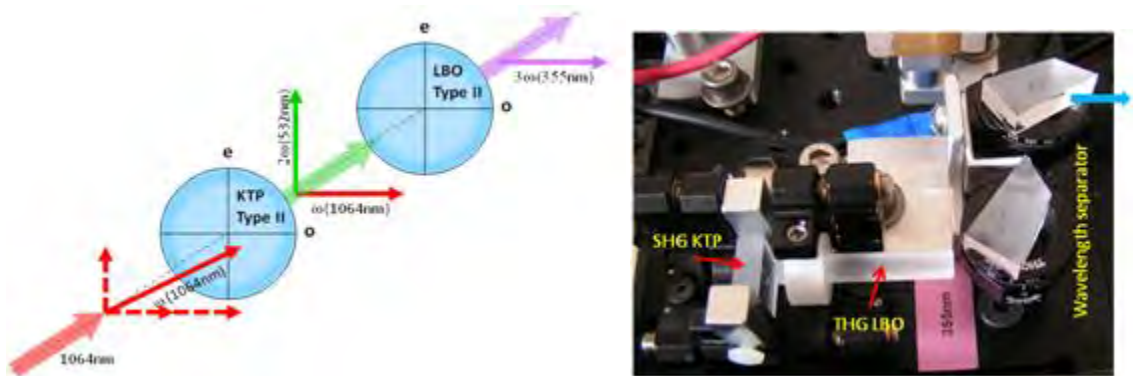The set-up for generating the third harmonics of 355nm is shown in figure 16.

Figure 16 – *355nm converter set-up using SHG followed by a THG*

The wavelength separation is done via the two Pellin-Broca prisms. We obtained up to 6mJ/pulse in the third harmonics.

Figure 17 shows the pulse energy and the temporal pulse of the third harmonics.
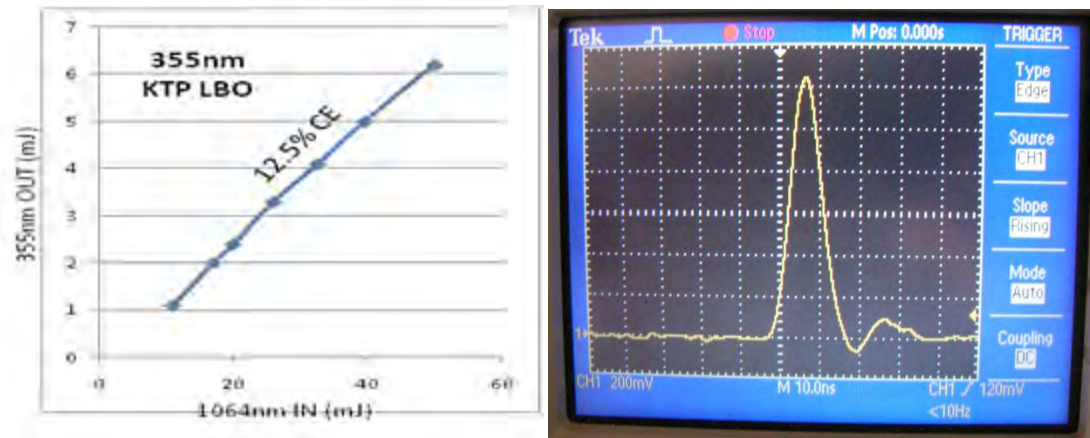
Figure 17 – *355nm converter pulse energy temporal pulse (9ns)*

266nm Converter

The set-up for generating the third harmonics of 355nm is shown in figure 18.
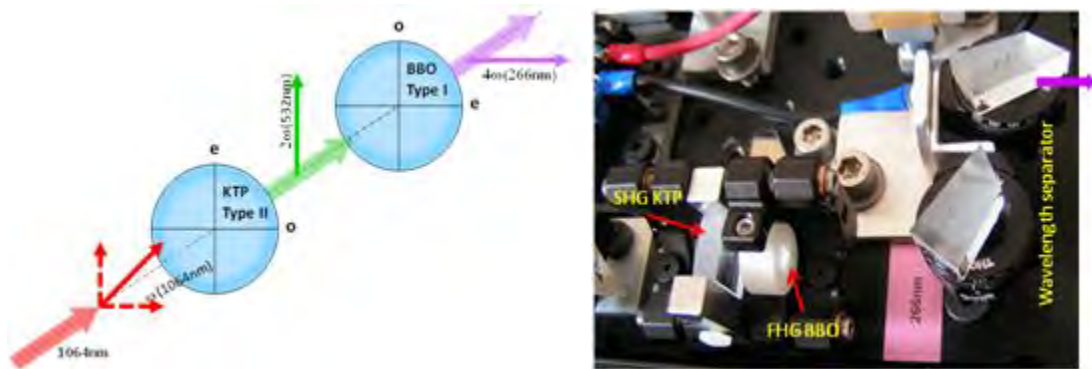

Figure 18 – *266nm converter set-up using SHG followed by a FHG*

The wavelength separation is done via the two Pellin-Broca prisms. We obtained up to 1.5mJ/pulse in the forth harmonics.

Figure 19 shows the pulse energy and the temporal pulse of the forth harmonics.
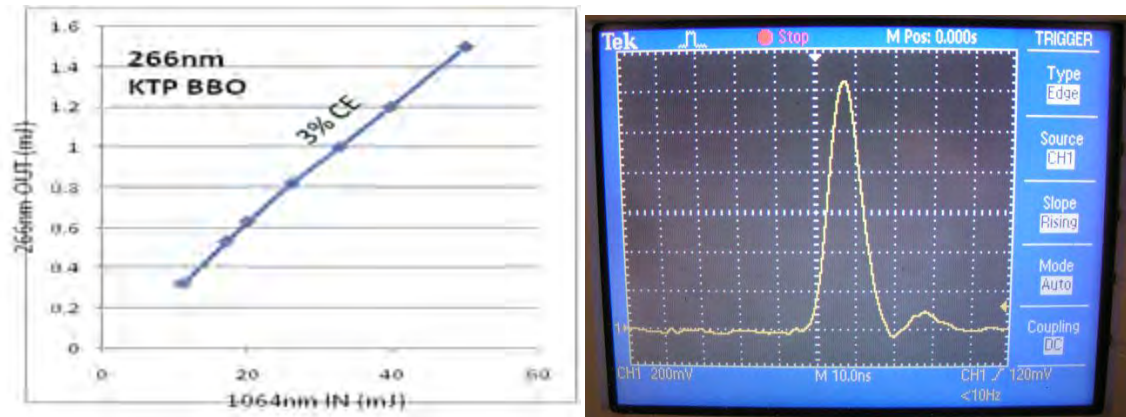
Figure 19– *266nm converter pulse energy and temporal pulse (10ns)*

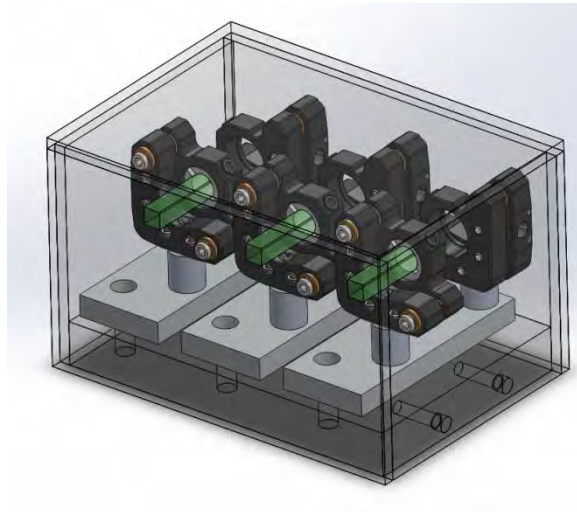Display cases for keeping the unused wavelength converters dust free were designed and fabricated (Figure 20)

Figure 20 –*SolidWorks model of display cases*

Figure 21 shows the storage enclosure for the three wavelength converters.

Figure 21– *Dust proof storage enclosure for the various wavelength converters*

Wavelength Separator

There are several ways to separate the wavelengths and point the desired beam in the right direction. We selected touse a pair of Pellin-Broca prisms for minimizing replacing optics at different wavelengths. But the angles of the prisms need to be adjusted to the desired wavelength in order to maintain the beam pointing.

Several different systems were considered and designed for mounting the PB prisms in such a way that they could be rotated accurately to the correct angles. (Figure 22)
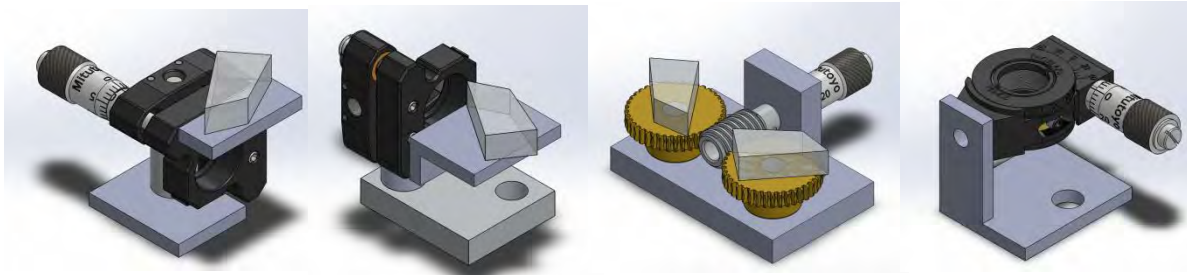

Figure 22–*PB Prism mount ideas*

A 3D printed model of the final design selection of the PB rotating mount was created (Figure 23)

Figure 23– *3D printed model of PB rotating mount*

The final successful implementation is shown in Figure 24.
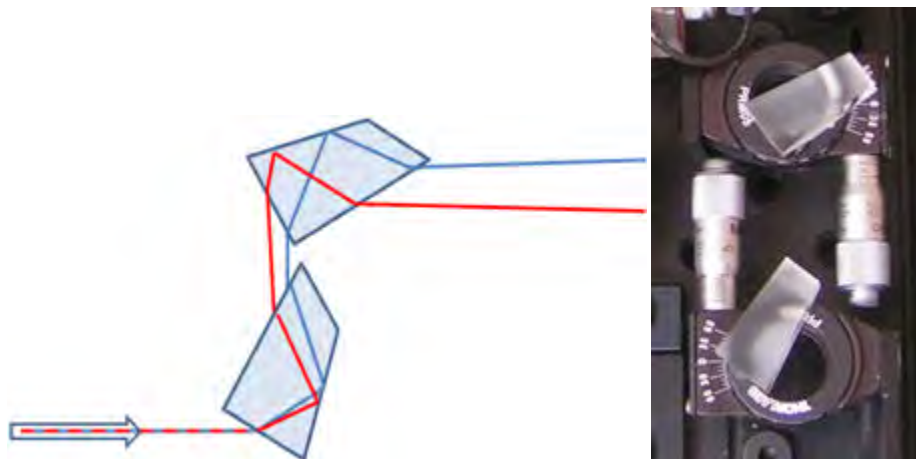
Figure 24– *Pellin-Broca prism arrangement for the wavelength separation*

Low Cost Design Considerations

The number one goal was low cost. One way that we managed to reduce cost was through the selection of optical components. Multiple vendors were sourced and a cost benefit analysis was performed to find the least expensive option that still meets all of the necessary specifications.

During the component selection process a table was created and constantly update to keep track of the cost, weight, and vendor of all the components for the setup. Cost estimates with price breaks for larger volume orders were also tabulated.

#	Part		Description	Model /manufact	Website Link	Cost	Wt	Detail	Qnty	order Total Price	1 off Total Price	LG Qnty Total Price
	Bread board /Case									$287.62		
1	Case		Enclosure		http://www.frys.com/product/2090841#det	$34.99			1	$34.99	$34.99	
2	Bread Board		Bread board (8" x 24")	MB824 Thor	http://www.thorlabs.com/thorproduct.cfm	$239.00		1/4-20 THD	4	$239.00	$79.67	
3	Grommett		Rubber mounting gromets	MSC	http://www.mscdirect.com/product/32828!	$16.09		1/4" ID 9/16" OD	100	$13.63	$0.41	
	Laser Head									$324.25		
1	Cube Holder	a	Mirror Mount	KM05FL Thor	http://www.thorlabs.com/thorproduct.cfm	$54.00	0.05		1	$54.00	$54.00	
		b	Inside ring	63392393 MSC	http://www.mscdirect.com/product/63392:	$3.66		3/8" ID by .5" OD	1	$3.66	$0.05	
		c	Outside ring	63392419 MSC	http://www.mscdirect.com/product/633924	$10.57		.5" ID by .75" OD	1	$10.57	$0.15	
		c	Outside ring 2	63392443 MSC	http://www.mscdirect.com/product/633924	$14.67		.75" ID by 1" OD	1	$14.67	$0.20	
		d	Set Screw	67348003 MSC	http://www.mscdirect.com/product/67348(	$13.11		6-32 at 1/4"	1	$13.11	$0.13	
		e	L-Bracket	6957823 MSC	http://www.mscdirect.com/product/069578	$15.03		1/8" by 1"	1	$15.03	$0.31	
		f	Plastic riser	63392229 MSC	http://www.mscdirect.com/product/633922	$6.11		3/8" by 3/8"	1	$6.11	$0.08	
		g	Post 1/2"	MS05R	http://www.thorlabs.com/thorproduct.cfm	$5.60	0.01	4-40 thd	1	$5.60	$5.60	
		h	Thread adapter	AP8E4E	http://www.thorlabs.com/thorproduct.cfm	$1.90	0	8-32 t0 4-40	1	$1.90	$1.90	
2	Mounting plates	a	Mounting plate small	32000739 MSC	http://www.mscdirect.com/product/32000;	$6.65		3/4" by 1/4"	3	$19.95	$0.83	
		b	Mounting plate xlarge	Amazon	http://www.amazon.com/gp/product/B000	$4.24		1.5" by 1/4"	1	$4.24	$4.24	
		c	Mounting plate thick	Amazon	http://www.amazon.com/gp/product/B000	$8.64		1.5" by 1/2"	1	$8.46	$4.23	
		d	Mounting plate large	32000747 MSC	http://www.mscdirect.com/product/32000;	$7.38		1" by 1/4"	3	$22.14	$4.92	
3	Mounting screws	a	Mounting screw from bottom	MSC	http://www.mscdirect.com/product/055740	$9.45		4-40 FLAT 3/4"	100	$9.45	$2.36	
		c	Mounting screws from top	MSC	http://www.mscdirect.com/product/98678:	$12.36		1/4-20 low head	100	$12.36	$1.48	
4	Farady Rotator	a	Outside ring	63392419 MSC	http://www.mscdirect.com/product/633924	$10.57		.5" ID by .75" OD	1		$0.15	
		b	Set Screw	67348003 MSC	http://www.mscdirect.com/product/67348(	$13.11		6-32 at 1/4"	1		$0.13	
5	Cube Holder 2	a	Mirror Mount	KM05FL Thor	http://www.thorlabs.com/thorproduct.cfm	$54.00	0.05		1	$54.00	$54.00	
		b	L-Bracket	6957823 MSC	http://www.mscdirect.com/product/069578	$15.03		1/8" by 1"	1		$0.31	
		c	Plastic riser	63392229 MSC	http://www.mscdirect.com/product/633922	$6.11		3/8" by 3/8"	1		$0.08	
		d	Post	MS05R	http://www.thorlabs.com/thorproduct.cfm	$5.60	0.01	4-40 thd	1	$5.60	$5.60	
		e	Thread adapter	AP8E4E	http://www.thorlabs.com/thorproduct.cfm	$1.90	0	8-32 t0 4-40	1	$1.90	$1.90	
7	Turning Mirror	a	Mirror Mount	KM05FL Thor	http://www.thorlabs.com/thorproduct.cfm	$54.00	0.05		1	$54.00	$54.00	
		b	Post	MS05R	http://www.thorlabs.com/thorproduct.cfm	$5.60	0.01	4-40 thd	1	$5.60	$5.60	
		c	Thread adapter	AP8E4E	http://www.thorlabs.com/thorproduct.cfm	$1.90	0	8-32 t0 4-40	1	$1.90	$1.90	

Table 1– *Optical component spreadsheet comparison list*

One way that was found to reduce cost, weight and size was to design and fabricate custom mounting plates for the optics. (Figure 25)
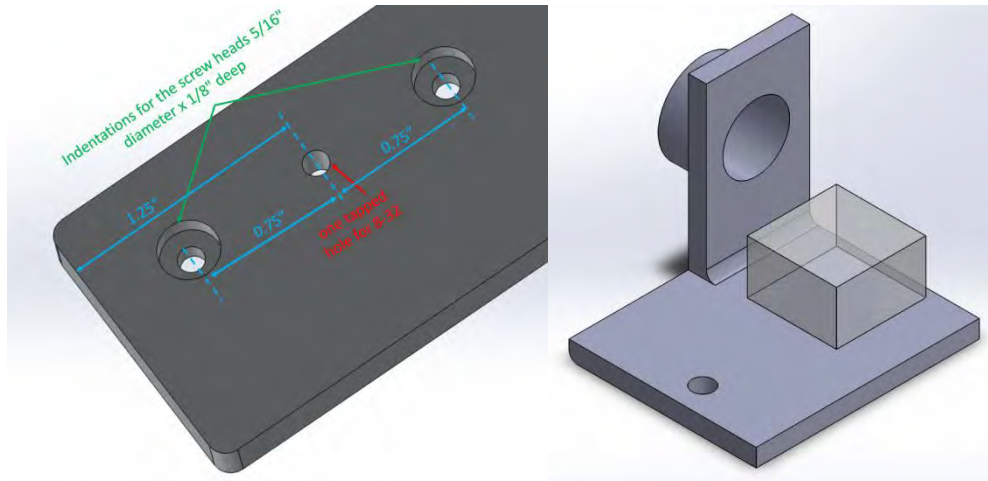

Figure 25– *CAD model of custom mounting*

An enclosure was selected and designed for the breadboard layout.   This was again modeled in SolidWorks. Along with the enclosure, an anti-vibration system was designed for the case using rubber grommets. (Figure26)
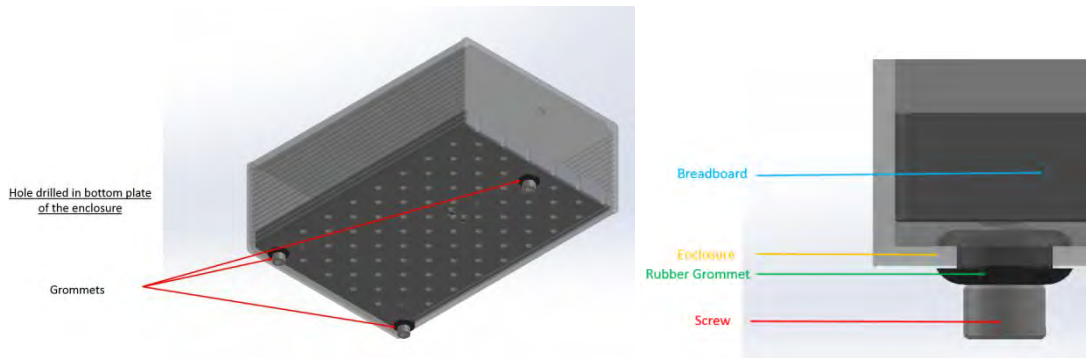
Figure 26– CAD model of case with grommets

Another way to keep the cost low was to research the most cost effective methods for fabrication of components. Larger volume runs for machining and anodizing lead to large cost savings per part in the long run.

Before having parts fabricated, a 3D model was printed to verify dimensions and clearances. (Figure 27) These parts were assembled on the breadboard to verify clearance and fit.
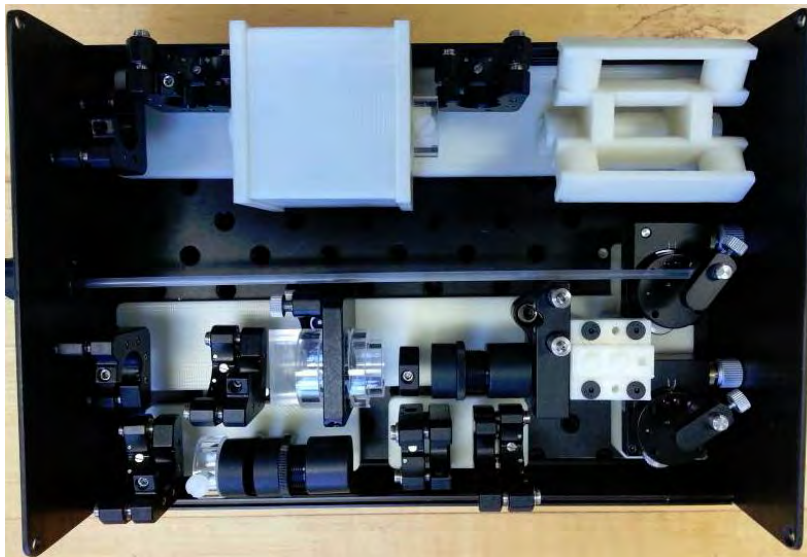

Figure 27– 3D model

After mocking up the system with the 3D parts, any modifications that were needed were then updated in the SolidWorks model. This process of drawing modifications followed by a 3D mockup was repeated several times before converging on a final design with correct dimensions. (Figure 28)
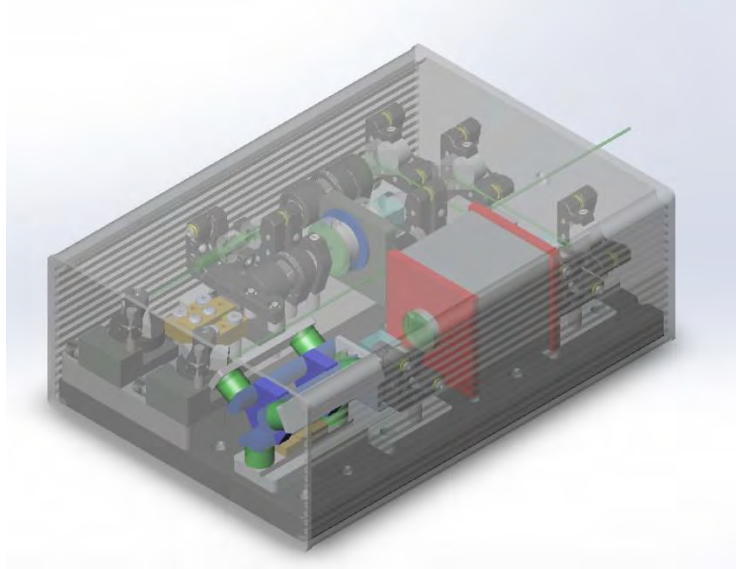
Figure 28– *CAD model of breadboard and case assembly*

Once this final design was updated for the SolidWorks model, all of the individual parts files that need to be fabricated were transformed into 2D CAD files. (Figure 29)
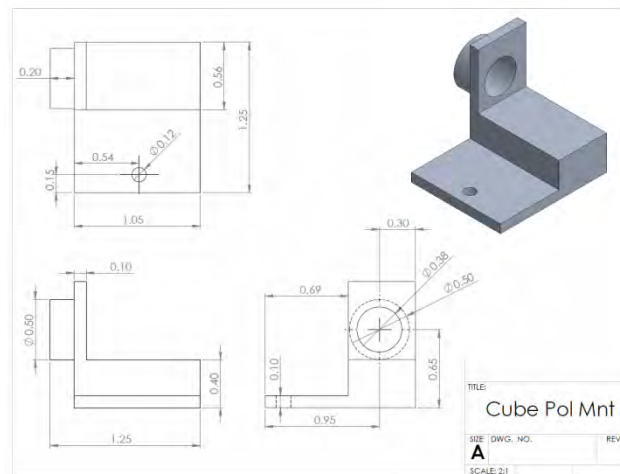

Figure 29– *2D CAD drawing of part to be fabricated*

These drawing files were then sent over to the machine shop where the parts were created using the correct materials (aluminum for the majority of parts). These parts were then mounted to the bread board just as the 3D printed parts had been, and again double checked for clearance fit and positioning. (Figure 30)
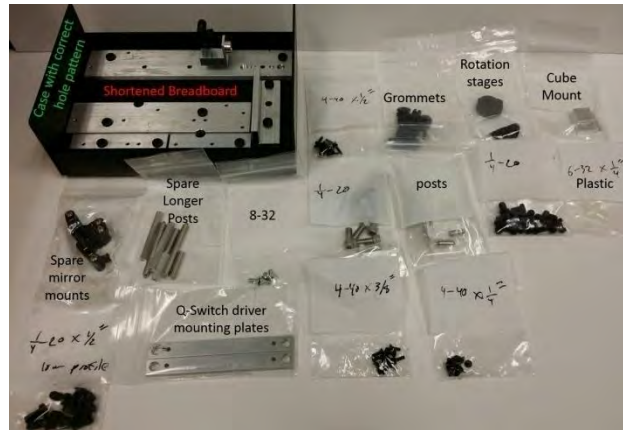
Figure 30 – Machined components

After any modifications were done to these parts and the final version was converged upon, the parts were then sent off to be anodized. The final anodized parts were assembled back on the bread board. (Figure 31)
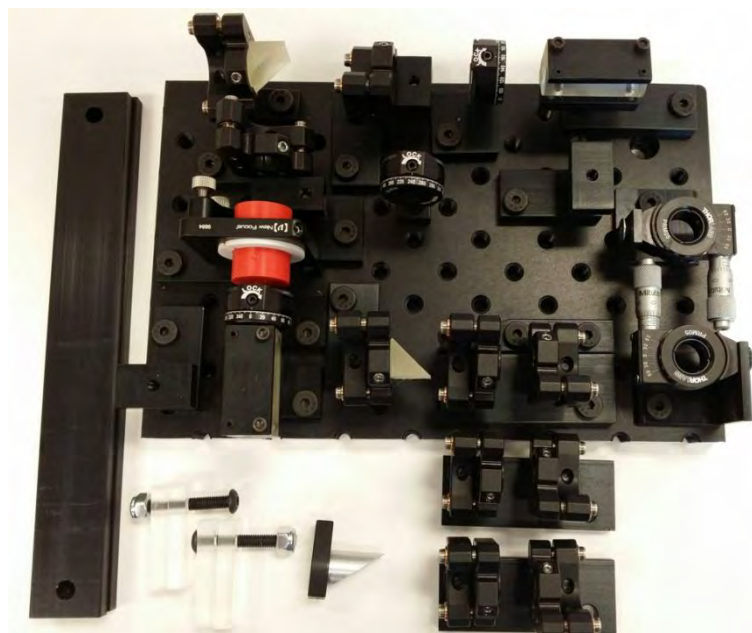

Figure 31– Anodized Parts assembled on breadboard

Another way to reduce costs, along with saving weight and space, was in the creation of custom parts. It was found that in several cases this proved to be cheaper and more efficient than purchasing an existing off the shelf product that may still need to be modified. One of these custom pieces was the laser rod mount design, which was first designed in SolidWorks. (Figure 32)
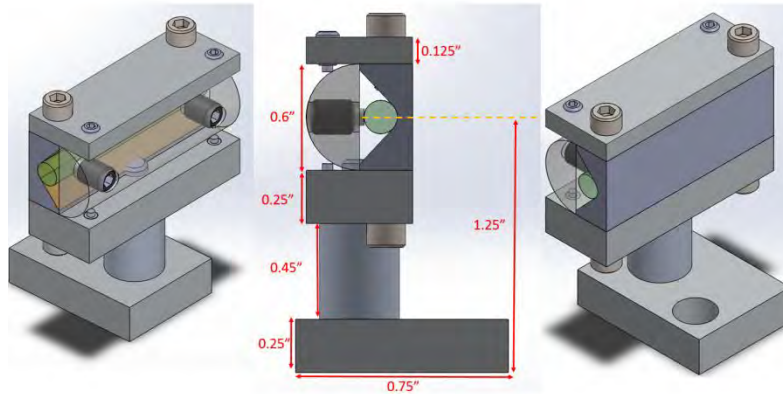
Figure 32 *– Custom designed laser rod mount*

As new parts were designed and added, and old parts were modified, the overall system assembly was continuously updated to reflect these revisions. (Figure 33)
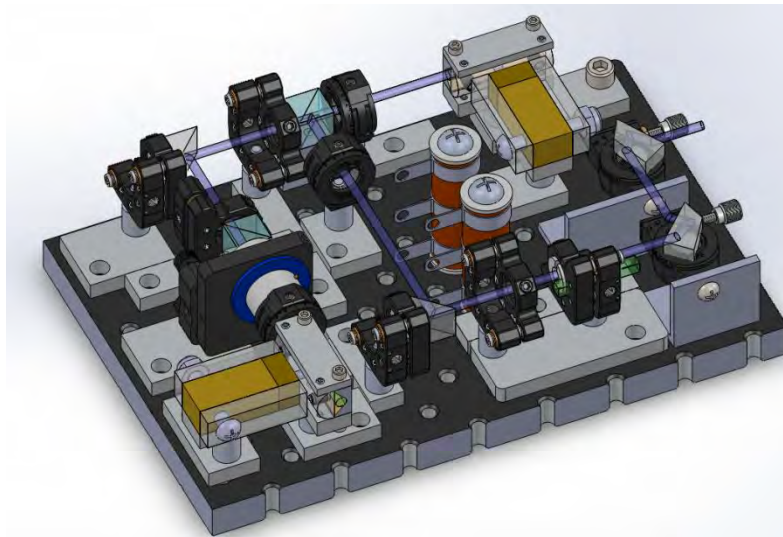

Figure 33 *– SolidWorks model of new system design*

After the new version of the system was completed in SolidWorks, the parts were then sent to the 3D printer and a mockup was assembled using these parts. (Figure 34)
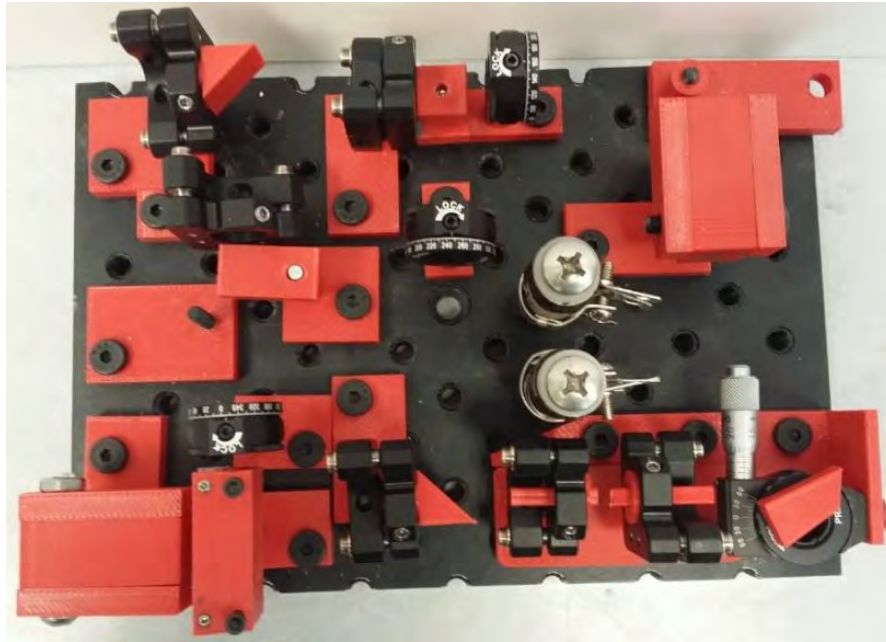
Figure 34 – System layout mockup using 3D printed components

After the clearance and fit of the parts were verified with the 3D print parts mock up, the next step was to send the drawings of these parts to the machine shop to be fabricated. Many of these parts would also need to be anodized as well. A layout of the parts that were to be anodized was created in SolidWorks. (Figure 35, 36)
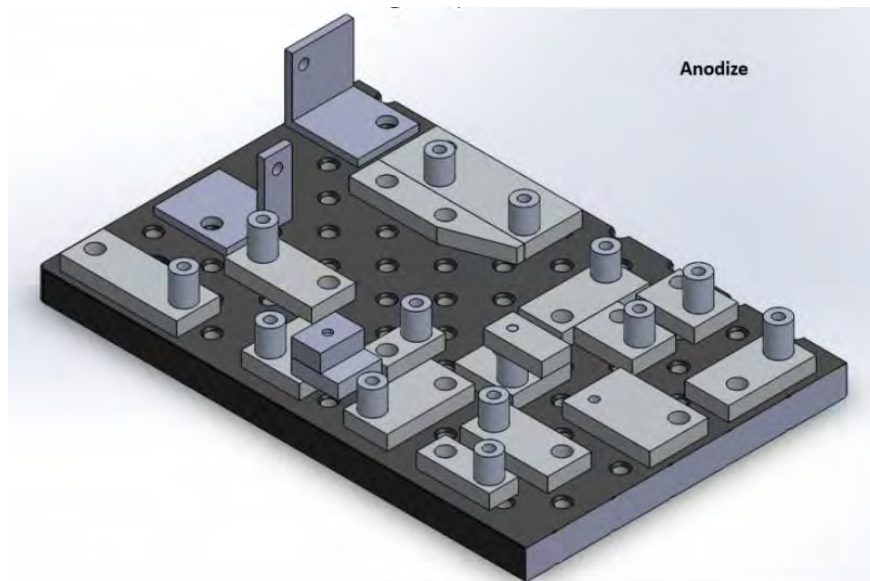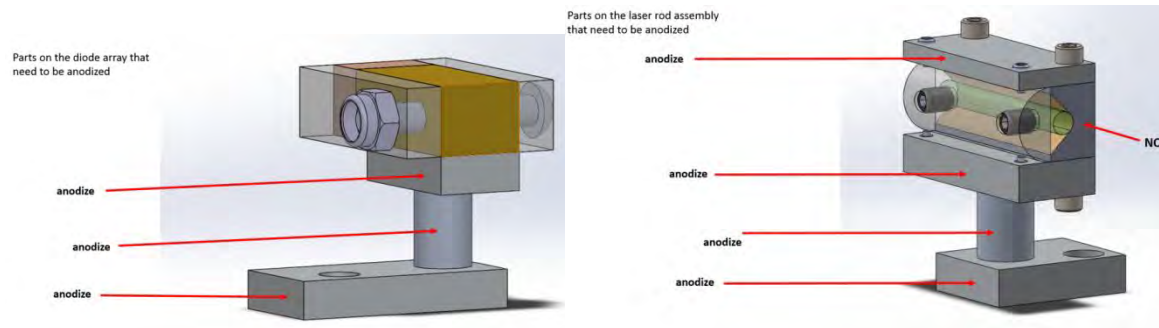

Figure 35 – Parts to be anodized

Figure 36 – Parts to be anodized

After several further modifications and adjustments to the layout design, mounts and components, multiple boards were populated with anodized parts. (Figure 37)
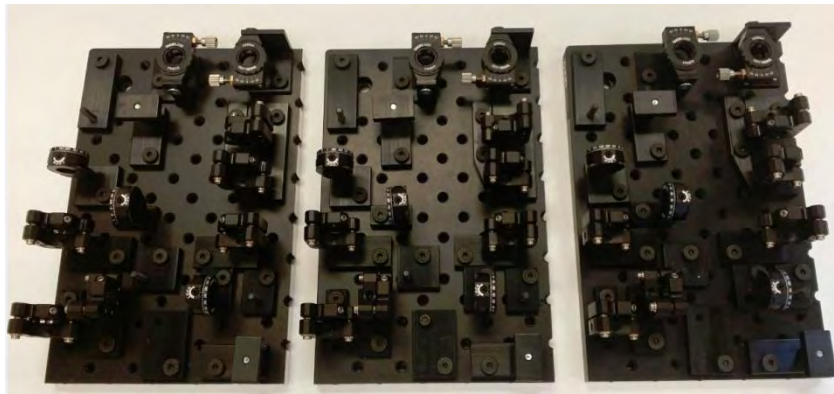

Figure 37 – Multiple boards populated with anodized parts

These boards were then fitted into the rubber mounted packaging cases (Figure 38)

Figure 38 –Populated with anodized parts mounted in enclosure

Compact Low Cost Laser Driver

The laser driver contains: 1) An internal pulse oscillator for generating 1Hz, 10 Hz, and 100Hz. 2) A pulse width modulator to vary the drive pulse duration which control the laser output pulse energy. 3) A high current electronic switch to drive the diode arrays. 4) A trigger pulse for the Q-switch driver. 5) A push button to activate the laser. 6) A trigger IN and a trigger OUT for synchronizing with other detection equipment. Figure 39 shows the block diagram of the laser driver.
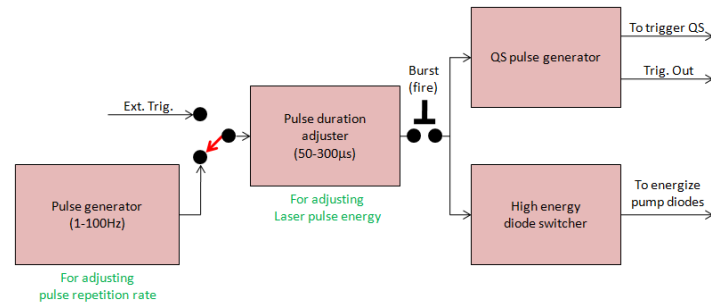

Figure 39– *Block diagram of the laser driver*

We developed and successfully tested a laser driver for burst mode operation. Commercial drivers are designed and built for continuous operation and not burst mode. Therefore, they are larger and very expensive. Our driver is extremely inexpensive. The material cost is under $50 and it can be packaged into a 1.5"x2"x5" enclosure. It contains the power supply and drive electronics. It also contains a trigger to automatically trigger the Q-switch and trigger IN and trigger OUT for synchronizing with a detection system. Figure 40 shows the driver and the current pulse it generates to drive the entire set of diodes used in the laser system.
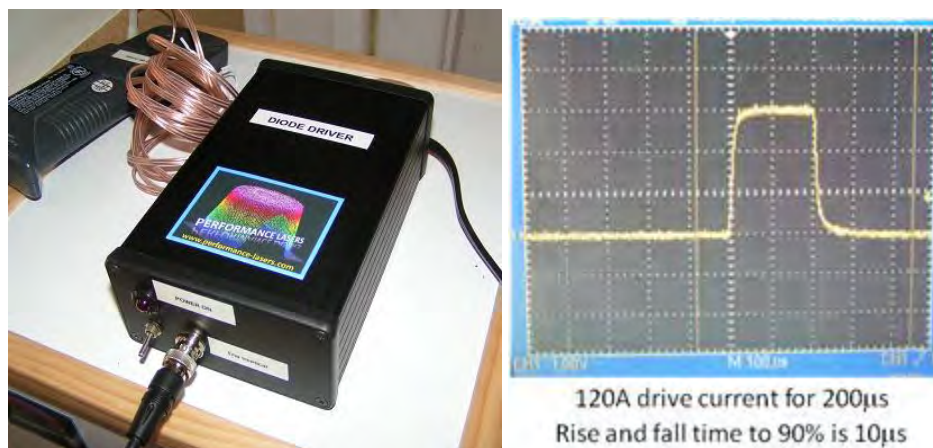

120A drive current for 200μs
Rise and fall time to 90% is 10μs

Figure 40 – *Extremely compact and low cost laser driver (includes power supply, diode driver, and Q-switch trigger) and it's current pulse*

The drive electronics is capable ofdelivering up to 500A peak current. The driver was tested under all of the required burst modes conditions and is currently used to drive the laser system.

Low Cost Q-Switch Driver

A commercial Q-switch driver costs nearly $2,000. We had to reduce the cost of the Q-switch driver to meet the goal requirements. We designed a new circuit and constructed it. Figure 41 shows the new compact Q-switch driver.
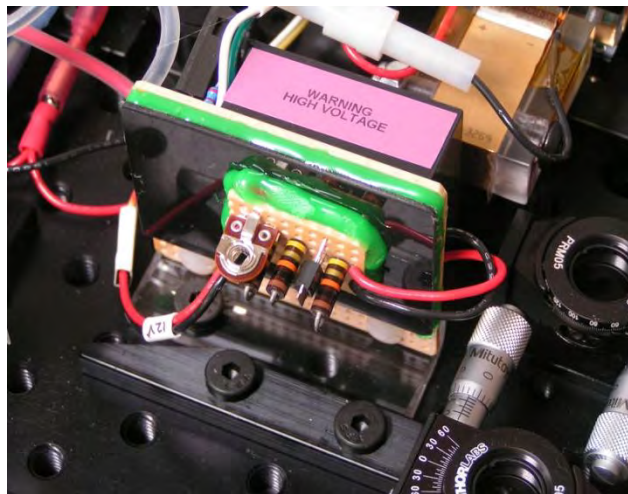

Figure 41 – Extremely compact and low cost Q-switch driver

The material cost of the driver is under $150 which is about 1/10 of the cost of a commercial driver. We did not have a single failure of the new Q-switch driver.

Battery / Inverter Pack

The power consumption of the burst laser is about 2W for 1Hz continuous operation, and about 20W at 10Hz burst. During the OFF time between bursts, the power consumption is only few mW. Therefore, the average power consumption is very low.

Since the average power required is low. A battery can be used to run the laser for autonomous field operation or on small robotic vehicles. In order to widen the potential applications of the laser system, 12Vdc would be the preferred choice since most vehicles has 12V battery. A rechargeable12V polymer Li-ion battery pack was constructed to power the laser system. An inverter to convert the 12Vdc to 115Vac is used; therefore, plugging the laser power cord to the inverter instead of the wall plug enables us to use the laser system in the field.

A case for external battery power supply needed to be designed and built. This case needed to be low cost, lightweight, portable, suitable for outdoor applications and easy to carry.   An initial design was created in SolidWorks for an insert to hold the batteries, inverter and wiring in place inside of a rugged off the shelf carrying case. (Figure 42, 43)
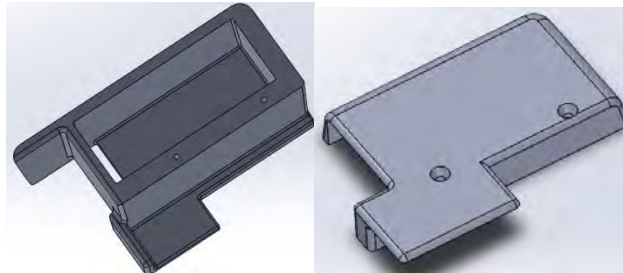

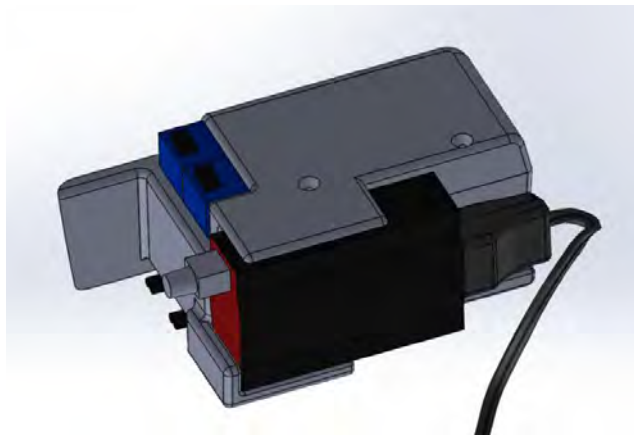*Figure 42 –SolidWorks model design for battery case insert*

Figure 43 –SolidWorks model assembly for battery case insert

After the SolidWorks design was revised and finalized the model was then converted to the appropriate file type and sent to the 3D printer. This 3D insert was installed in the Pelican case along with the batteries, inverter and wiring. (Figure 44)

Figure 44 – Polymer Li-ion battery for powering the burst laser system

Complete Systems

A photograph of the complete system is shown in figure 45. It contains the laser module, the laser driver unit that plugs to 115Vac and the wavelength converters that can be inserted into the laser module for operating at 1570nm, 355nm, or 266nm.

Figure 45 *– Complete laser system (laser module in center, laser driver on left, and wavelength converters on right)*

The laser system and battery pack are housed in a small briefcase (18"x13"x6") for easy transportation and storage. (Figure 46)

Figure 46 *– Burst laser in a briefcase*

Figure 47 shows the fully completed three prototypes burst lasers in their briefcases.

Figure 47 – Three completed prototype burst lasers in their briefcases

Manual

A manual like the one shown in figure 48 for powering and operating the burst laser is attached to each of the laser systems. The burst laser is maintenance free and the operator should not attempt to troubleshoot or repair the laser system.
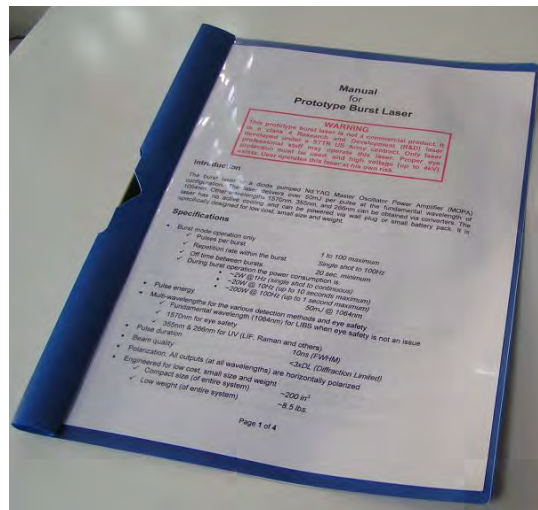

Figure 48– Operator manual for the prototype burst laser

Cost Estimates

The cost to produce the burst laser is the number one goal. We have made every effort to minimize the cost of the system. We were able to build a laser system for a total material cost of about $5,500 (not including wavelength converters and battery pack). The options for wavelength converters, wavelength separator, and battery pack will add to the material cost about $2,000. High volume production should reduce the material cost at minimum by 25% and possibly by over 50%. Therefore, the selling price per unit at high volume may well be under $8,000.

Estimates of Technical Feasibility

The final goal is to have low cost and compact commercial burst lasers to be integrated in CBRNE detection applications. Phase II clearly demonstrated the feasibility of clearing the way toward commercial systems that meet the desired low cost, size and weight. With the design and component selection of this prototype it was possible to reduce the cost as compared to the present readily available lasers on the market that have comparable specifications.

The prototype laser has been designed to be used indoor and in outdoor field scenarios. The size and weight was optimized so that the laser and battery pack could easily and comfortably be carried. The packaging was also designed to be rugged and to reduce vibrations.

All that is left to do is: 1) add temperature control to expand the current range of 70F – 80F to a wider range if needed, 2) control the laser remotely via WiFi, Blue Tooth, etc. with smart phone if needed, 3) add safety features like interlocks, warning lights, etc. if needed, 4) do reliability, shake and bake testing, and 5) engineer it for mass production.

The transition time to mass production will vary on the added requirements, but should take as low as one year and up to three years at the most.